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TR 66-96

TECHNICAL REPORT NO. 66-96

QUARTERLY REPORT NO. 5
PROJECT VT/5051, DEEP-WELL RESEARCH

TELEDYNE INDUSTRIES
GEOTECH DIVISION
GARLAND TEXAS

TECHNICAL REPORT NO. 66-96

QUARTERLY REPORT NO. 5
PROJECT VT/5051, DEEP-WELL RESEARCH

by

Richard M. Shappee
Eduard J. Douze

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ILLUSTRATIONS

ABSTRACT

A vertical-array of four triaxial short-period seismographs was operated at Apache, Oklahoma. The outputs of the seismographs were digitally recorded.

Single-channel optimum filters were developed and tested off line. Deghosting filters were used in conjunction with the optimum filters.

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QUARTERLY REPORT NO. 5
PROJECT VT/5051, DEEP-WELL RESEARCH

1. INTRODUCTION

This report discusses a project in deep-hole seismology. The work reported herein includes the development and operation of a short-period triaxial seismometer array, development of digital analysis techniques, and expansion of the digital field system to include computational capability.

The purpose of this report is to present the technical accomplishments of this project for the period from 1 July 1966 through 30 September 1966; it is submitted in compliance with paragraph 2, Reports, of the Amended Statement of Work to be Done, AFTAC Project Authorization No. VELA T/5051 dated 19 May 1965. The project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and under the overall direction of the Advanced Research Projects Agency (ARPA).

The main body of the report is presented in the same sequence as the tasks in the Amendment to the Statement of Work. The Statement of Work of Amendment No. 6 is included as an appendix to this report.

2. ASSEMBLE AND OPERATE TRIAXIAL-ARRAY SYSTEM, TASK 1e

The triaxial-array system operated throughout the reporting period. Some changes were made in the system to adapt it to requirements of the digital system. The gain of the summing amplifiers was increased to give larger excursion of the digitizer. Another change was the incorporation of a Signal Isolator, Model 6722-A to remove dc offsets from the summation traces. The remaining change was to incorporate provisions to easily adjust the level of the analog signals from the 16-channel digital-to-analog converter. This last change has not been completed because the supplier of the D-A has not made delivery.

During the quarter, a computer program was written for on-site use to list recorded data in integer form. Figure 1 shows the presentation of the data which results from this program. The program has greatly increased the precision of calibration of the seismographs.

SITE=APOK DAY= 235 HOUR= 23 MIN.= 2 SEC.= 39 FILE=62 RECORD=4

CH. 1	CH. 2	CH. 3	CH. 4	CH. 5	CH. 6	CH. 7	CH. 8	CH. 9	CH. 10	CH. 11	CH. 12	CH. 13	CH. 14	CH. 15	CH. 16
155	7	9	2	7 -	2 -	3	3	9 -	6 -	4	4	5	0	8 -	3
158	7	10	3	5	0 -	1	2	9 -	5 -	5	4	7	2	11 -	5
163	10	11	2	6	0 -	0	2	9 -	6 -	4	5	8	3	11 -	5
163	9	11	1	5	1 -	1	3	7 -	8 -	5	5	8	2	11 -	5
169	11	14	2	6	2 -	1	4	8 -	7 -	4	5	8	2	12 -	5
166	12	15	1	7	1 -	1	4	9 -	7 -	4	4	8	2	12 -	6
162	13	13 -	0	8	1 -	1	2	9 -	7 -	6	4	8	2	12 -	7
167	12	10 -	1	7	1 -	1	2	8 -	6 -	7	3	8	2	12 -	7
168	8	10	0	6	0 -	1	2	8 -	5 -	6	4	8	2	12 -	6
167	10	14	3	6	0 -	0	3	8 -	4 -	6	5	7	2	12 -	6
159	9	14	5	5	0 -	0	3	9 -	4 -	5	5	7	2	12 -	6
163	8	13	5	4	1 -	0	4	8 -	4 -	5	5	7	2	12 -	6
170	7	10	6	4	1 -	1	3	7 -	5 -	4	5	7	3	13 -	6
180	11	10	4	4	1 -	1	3	7 -	5 -	4	5	7	4	14 -	6
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183	17	15	4	5	2	1	2	8 -	5 -	5	5	7	6	14 -	6
174	16	18	3	4	1	2	3	9 -	5 -	4	4	7	6	13 -	6
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144	13	12	6	3	2	1	1	9 -	6 -	5	9	5	5	13 -	8
143	11	13	4	3	1	1	1	10 -	6 -	6	8	5	5	13 -	8
142	12	13	3	3	2	2	0	10 -	6 -	6	8	5	5	14 -	8
156	12	13	4	2	2	2 -	0	10 -	5 -	6	7	5	5	14 -	8
174	12	14	3	2	2	2 -	0	11 -	5 -	6	7	6	5	14 -	7
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138	9	10 -	2	2 -	1	0	2	9 -	6 -	6	3	5	5	11 -	6
137	6	8 -	2	2 -	2	0	1	8 -	5 -	7	2	5	5	11 -	6
142	6	5 -	2	3 -	3	0	1	6 -	5 -	6	3	5	4	11 -	6
139	5	2 -	2	4 -	3 -	0	1	6 -	6 -	6	3	4	3	10 -	5

Figure 1. Listing of data

3. CONTINUE DEVELOPING TECHNIQUES FOR IMPROVING THE SIGNAL-TO-NOISE RATIO, TASK 1f (1)

Signal-channel optimum filters have been calculated with the technique that uses deghosting filters. The processing scheme shown in Figure 2a was used, together with a set of digital band-pass filters (3.0 to 0.3 sec period). The band-pass filters were included to eliminate a small long-period drift detectable at the high magnifications being used; this drift affected the correlations and had to be eliminated. For on-line processing band-pass filters will not be used.

Single-channel optimum filters were used in this first step because it was hoped that they would afford a greater insight into the process. Multi-channel Wiener filters for the same techniques will be calculated next.

Figures 3a, 3b, 3c, and 3d show the results obtained. The spectra shown were obtained by passing the noise samples used to calculate the optimum filters through the process and calculating the spectra of the outputs. The seismometer at the surface (15.2 m) was used as a reference. As can be seen from the figures, the process using the bottom seismometer (2897 m) was the only one that resulted on an appreciable reduction of the noise level. The seismometer at 1063 m, used together with the surface, actually increased the noise level somewhat. The reason for this behavior is not known; however, considering that noise and signal amplitude-depth relationships are very similar at this site, the inverse filters would tend to make the noise at depth and at the surface very similar. The closer to the surface the more pronounced this effect would be. The optimum filters can probably not cope with this situation.

In order to check the correctness of the time-domain optimum filters, the filters were also calculated in the frequency domain. Figure 4 shows the frequency-domain optimum filter and the Fourier transform of the time-domain filter for a depth of 1063 m. The agreement between the two is not as good as expected. The differences may be caused by the averaging over several frequency bands which occurs in the spectra used in calculating the frequency-domain filter. The problem, if any, will be investigated further and will be discussed in the next report.

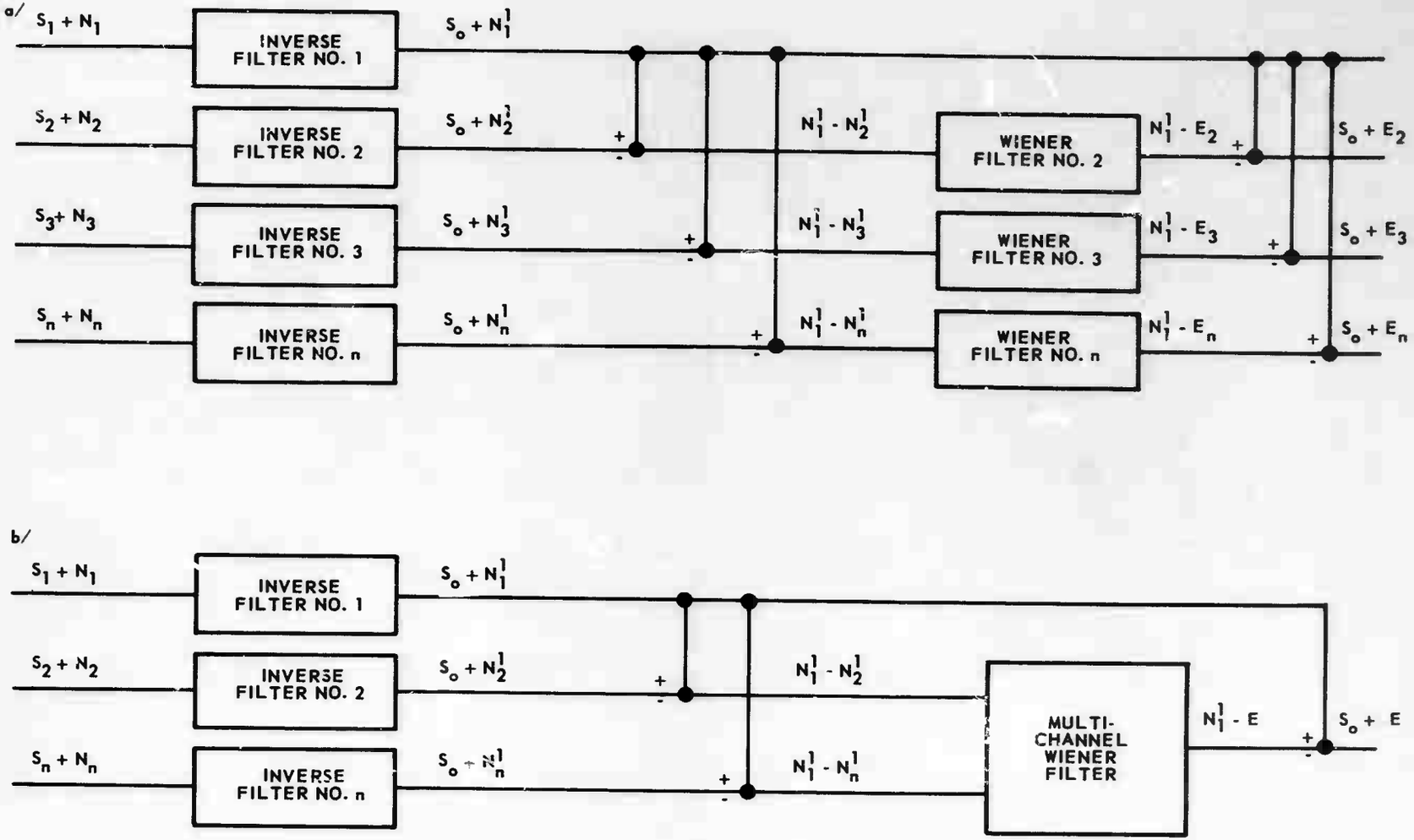

Figure 2. Deep-hole data processing techniques

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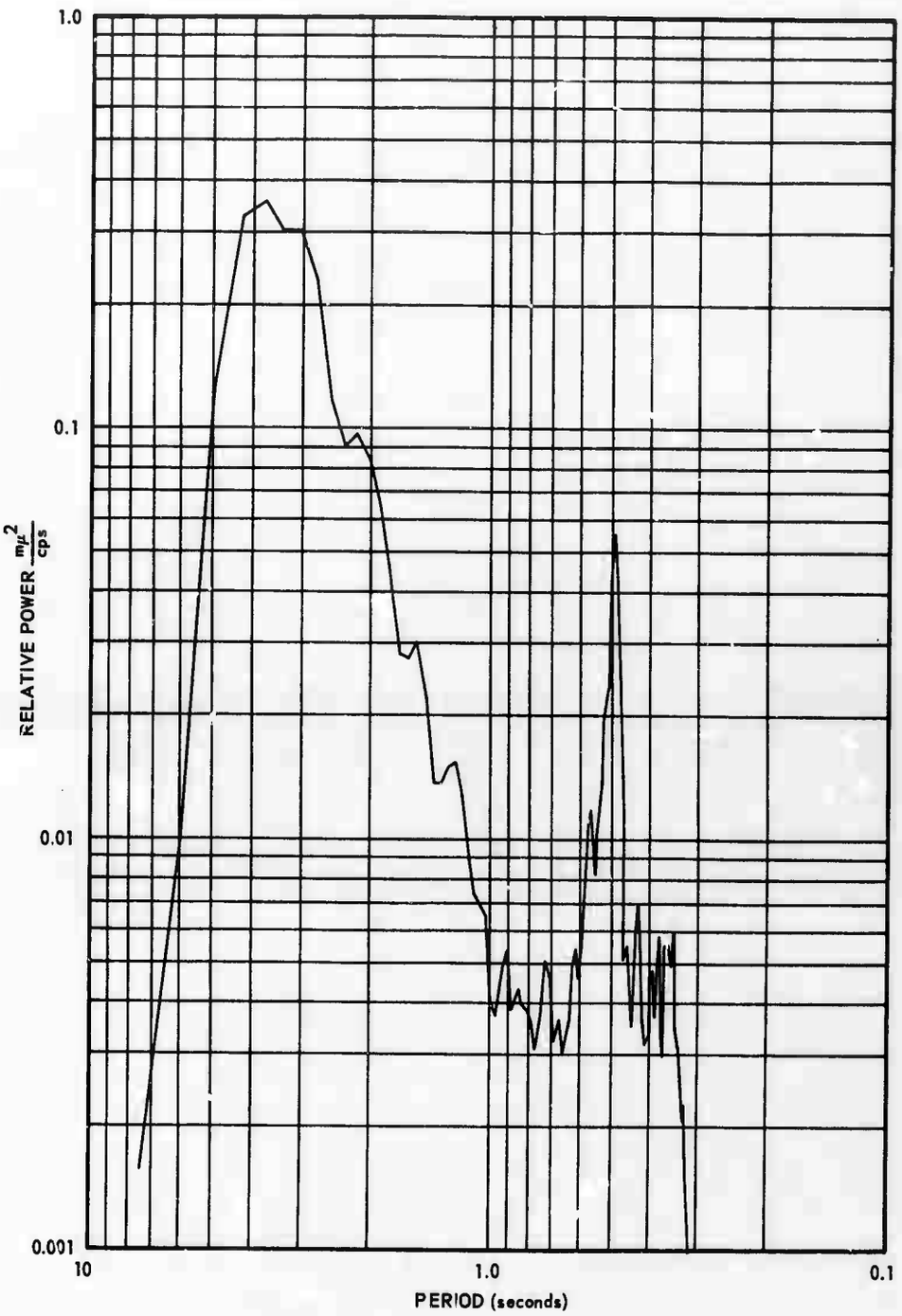

Figure 3a. Spectrum of the surface noise, AP-OK

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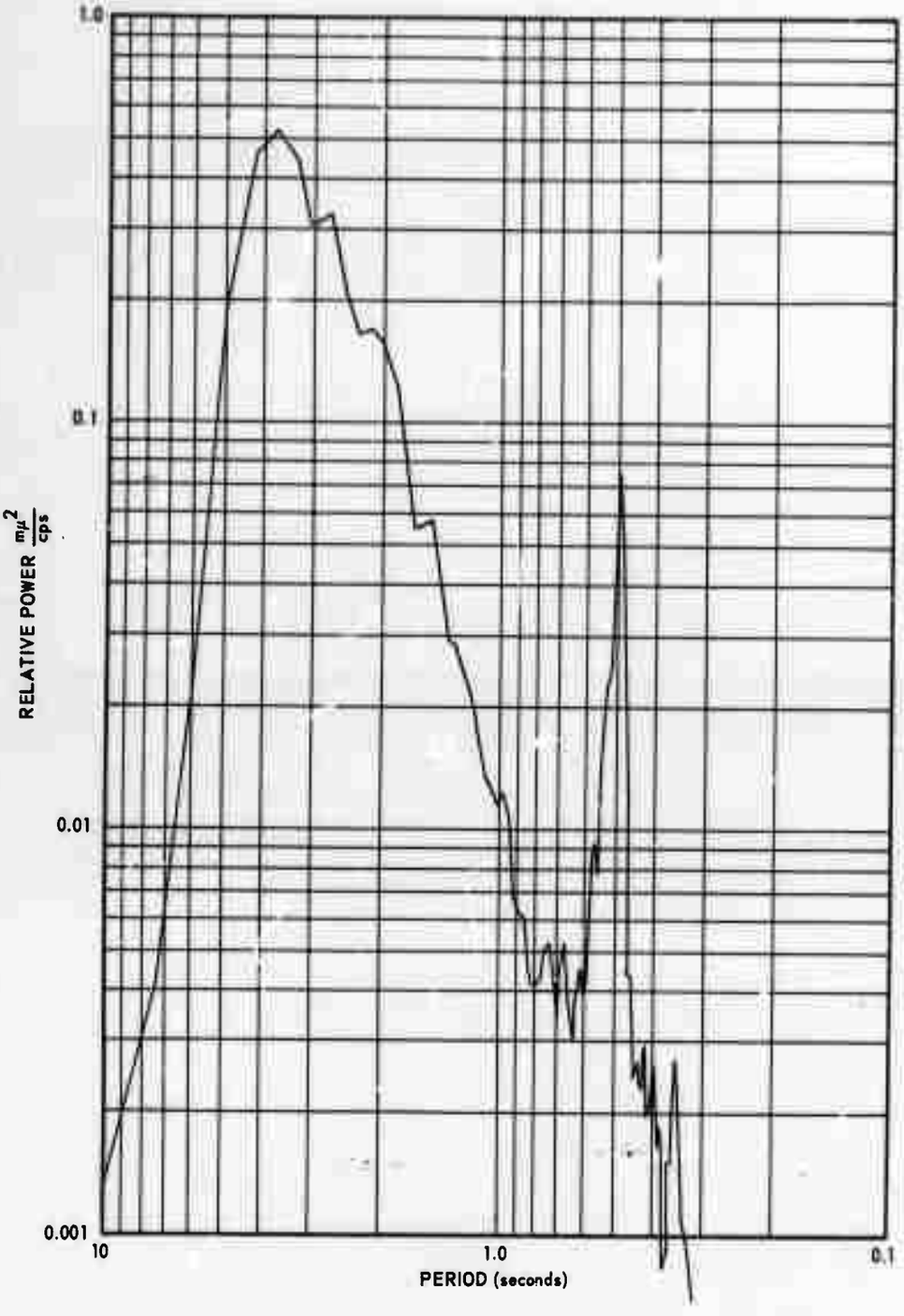

Figure 3b. Spectrum of the noise after optimum filtering using seismometer at 1063 m

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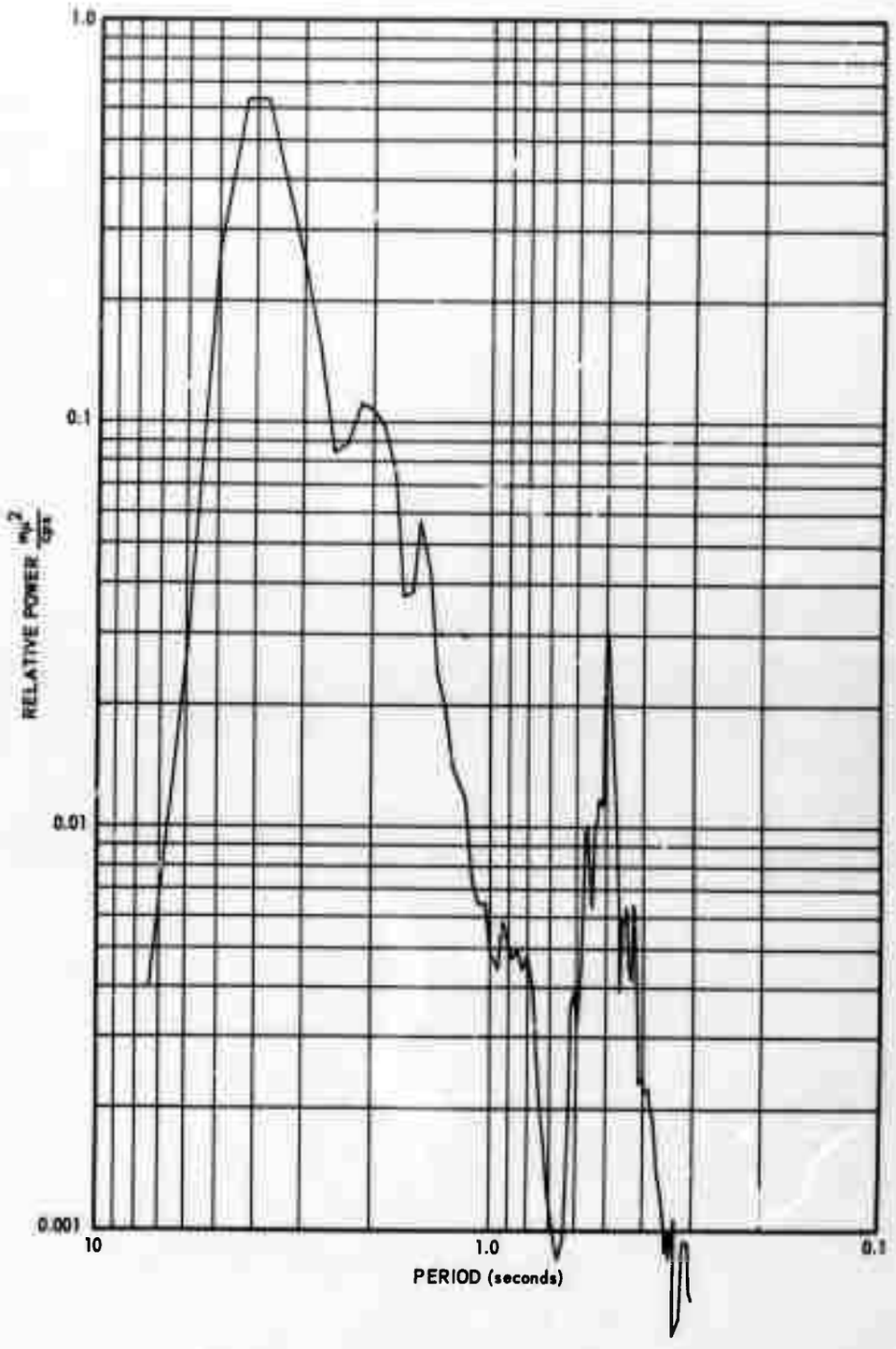

Figure 3c. Spectrum of the noise after optimum filtering using seismometer at 1983 m

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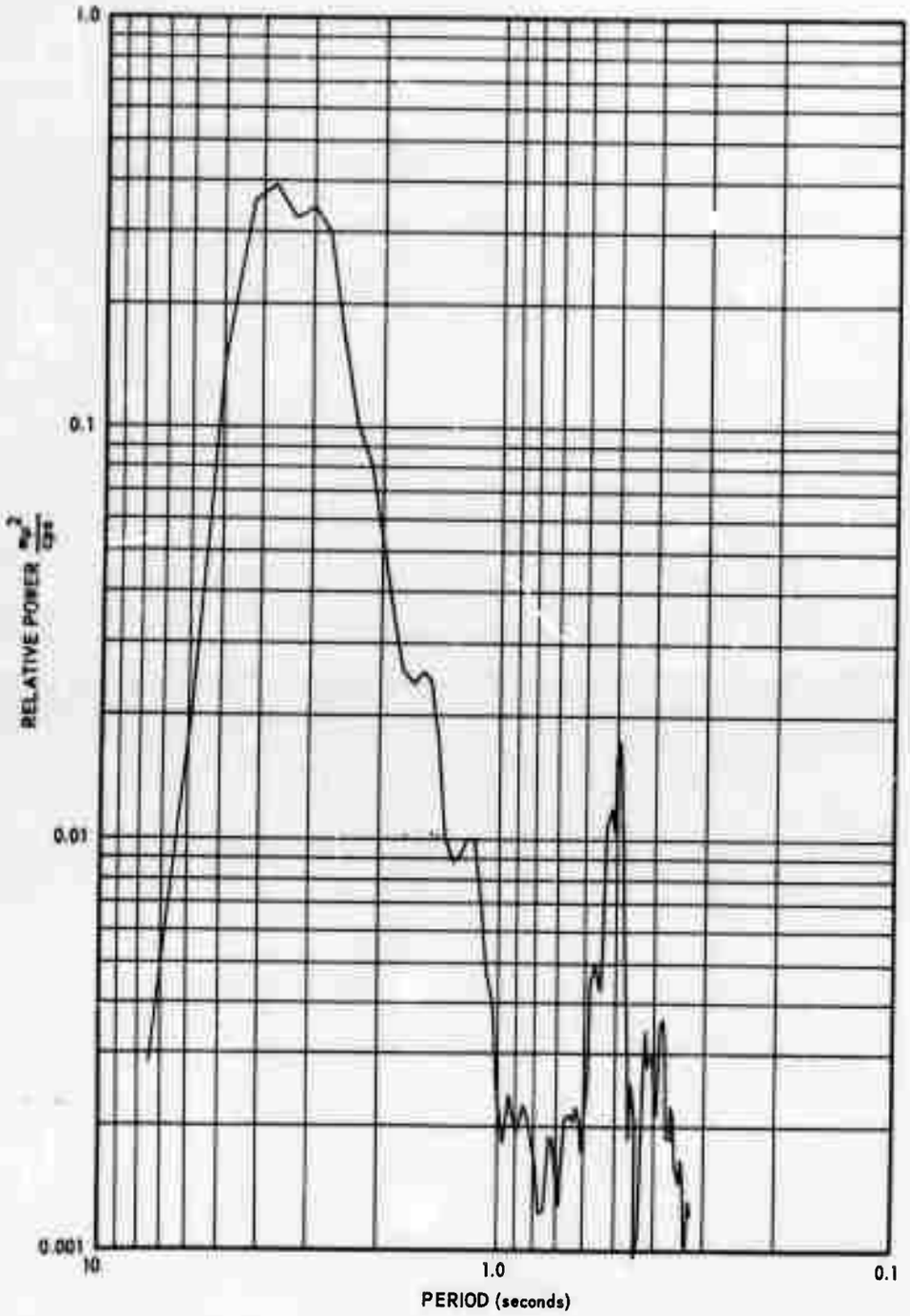

Figure 3d. Spectrum of the noise after optimum filtering using seismometer at 2897 m

G 1695

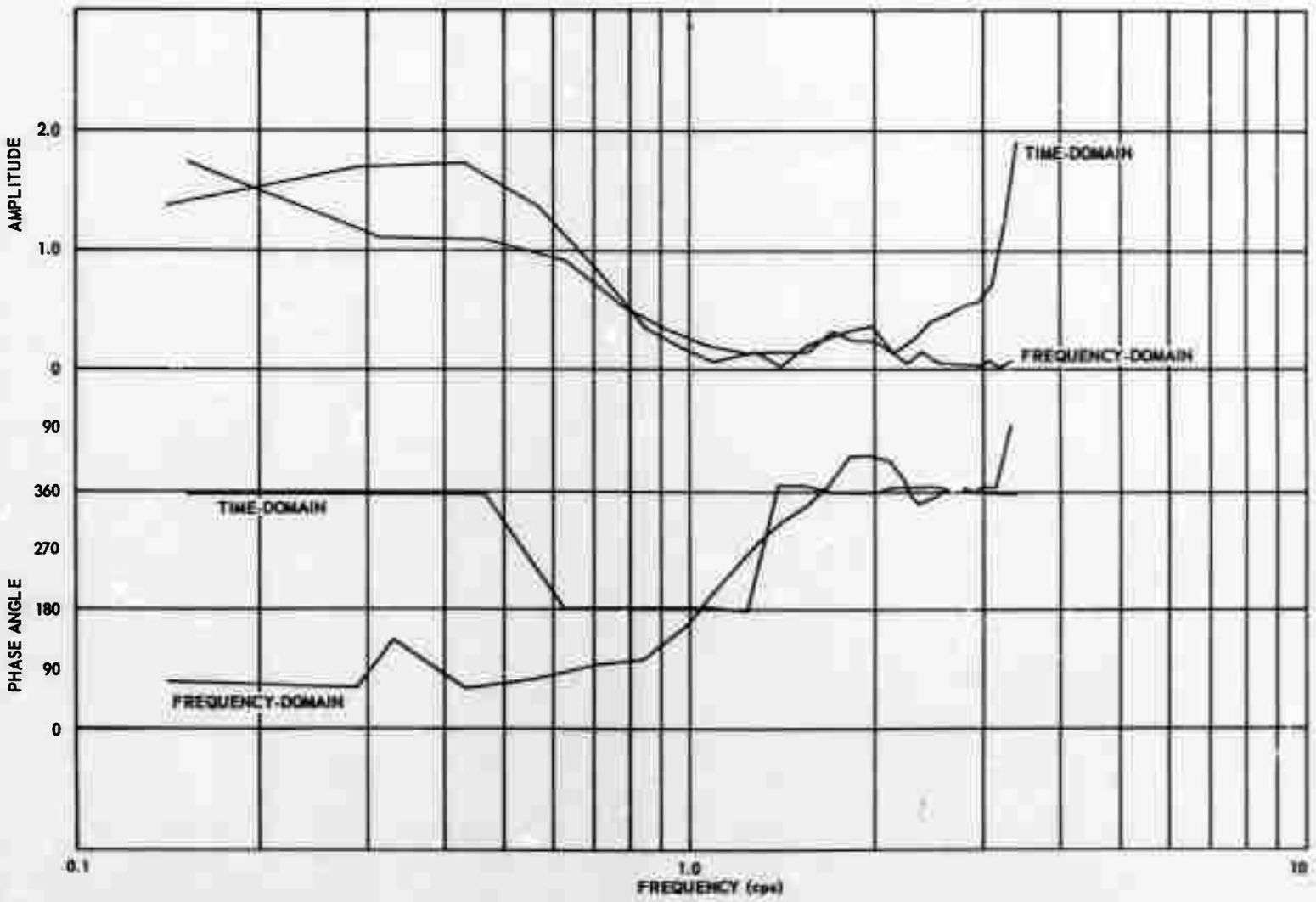

Figure 4. Comparison of the optimum filters calculated in time and frequency domains

G 1696

4. PROVIDE AND TEST AN ON-LINE SIGNAL PROCESSOR, TASK 1f (2)

The on-line signal processor, an Adage, Inc. Ambilog 200, exhibited unreliable performance through most of the reporting period. The manufacturer of the equipment modified its systems tapes and made new copies available to us in July with the result that for the first time we were able to use the digital system with confidence. In August, Adage made hardware modifications to the equipment and incorporated some changes in our digitizing program, both designed to reduce spurious noise in the system. After these changes, the system operated reliably until 21 September. At that time we experienced what appeared to be an intermittent in the memory. At the time this report is being written, it is not clear whether the fault lies in the memory or elsewhere in the computer.

Because of problems in obtaining satisfactory performance from the computer, we have been delayed in completing on-line processing programs. At this time, we are completing a program designed to do inverse filtering of the vertical summation of each triaxial seismograph. The program is written in such a way that we do not expect great problems in later including the Wiener filter routines.

When the inverse filter program is operational, we will ship tapes to our Garland plant. There we will off-line process them to provide an analog output on film. The D-to-A processing on line will be done as soon as the Adage equipment is received and installed.

APPENDIX to TECHNICAL REPORT NO. 66-96

AMENDMENT TO
STATEMENT OF WORK

AMENDED STATEMENT OF WORK TO BE DONE
AFTAC Project Authorization No. VELA T/5051

1. Tasks 1a, 1b, and that portion of Task 1c pertaining to oceanbottom testing, which have been completed, are deleted.

2. Task 1d and the rest of Task 1c, which are still applicable, are retained and enhanced by the following specific tasks:

a. Task 1e: Assemble and operate an easily transportable vertical-array system employing 3 to 6 triaxial short-period deep-well seismometers. Record deep-hole three-component data at deep-well sites to be designated by the AFTAC Project Officer. Analyze the data obtained to determine the behavior with depth of the horizontal and vertical components of signals and noise.

b. Task 1f: Continue developing techniques for improving signal/noise ratios and detecting low-level signals by processing data from vertical-borehole arrays of vertical and triaxial seismometers. Relate parameters of the processing techniques to varying conditions of seismic noise, seismographic system characteristics, geological structure, and geographic location. Provide and maintain an on-line vertical-array signal processing device and field test it at sites to be designated by the AFTAC Project Officer.

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13. ABSTRACT

A vertical-array of four triaxial short-period seismographs was operated at Apache, Oklahoma. The outputs of the seismographs were digitally recorded. (U)

Single-channel optimum filters were developed and tested off line. Deghosting filters were used in conjunction with the optimum filters. (U)

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